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Jeon

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(54) **SURVEILLANCE SYSTEM AND METHOD**

(71) Applicant: **HANWHA TECHWIN CO., LTD.**, Changwon-Si (KR)

(72) Inventor: **Ki-Yong Jeon**, Changwon (KR)

(73) Assignee: **Hanwha Techwin Co., Ltd.**, Changwon-si (KR)

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(51) **Int. Cl.**

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G01S 13/87	(2006.01)
G01S 13/00	(2006.01)
G01S 7/40	(2006.01)

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CPC ***G01S 7/4004*** (2013.01); ***G01S 13/003*** (2013.01); ***G01S 13/867*** (2013.01); ***G08B 13/19695*** (2013.01)

(58) **Field of Classification Search**

CPC G08B 13/18; G08B 13/189; G08B 13/194; G08B 13/196; G08B 13/19695; G01S 7/02; G01S 7/40; G01S 7/4004; G01S 13/003; G01S 13/86; G01S 13/867; G01S 13/87; G01S 13/878; G01S 13/88; G01S 13/89; G01S 13/90; G01S 13/9035; G01S 2013/9058

USPC .... 382/100, 103; 342/25 R–25 F, 27, 28, 342/52–55, 59, 118, 125–128, 133, 134, 342/139, 140, 165, 173–175, 195, 450–465, 342/169, 82, 89

See application file for complete search history.

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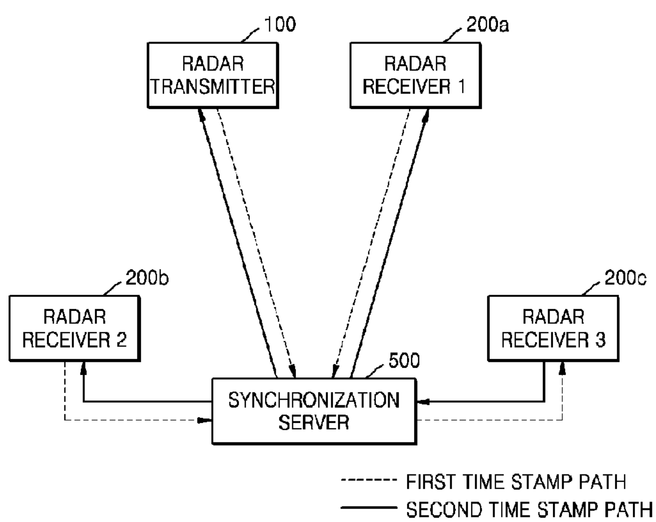
Primary Examiner — Bernarr Gregory

(74) *Attorney, Agent, or Firm* — Sughrue Mion, PLLC

(57) **ABSTRACT**

Provided is a surveillance system including a radar transmitter which transmits a detection signal to an object existing within a surveillance region, and at least one radar receiver which is installed separate from the radar transmitter within the surveillance region, receives a signal reflected by the object, and predicts a signal distance of the object which is a sum of a distance from the radar transmitter to the object and a distance from the object to the at least one radar receiver.

16 Claims, 10 Drawing Sheets



(51) **Int. Cl.**
G01S 13/86 (2006.01)
G08B 13/196 (2006.01)

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FIG. 1

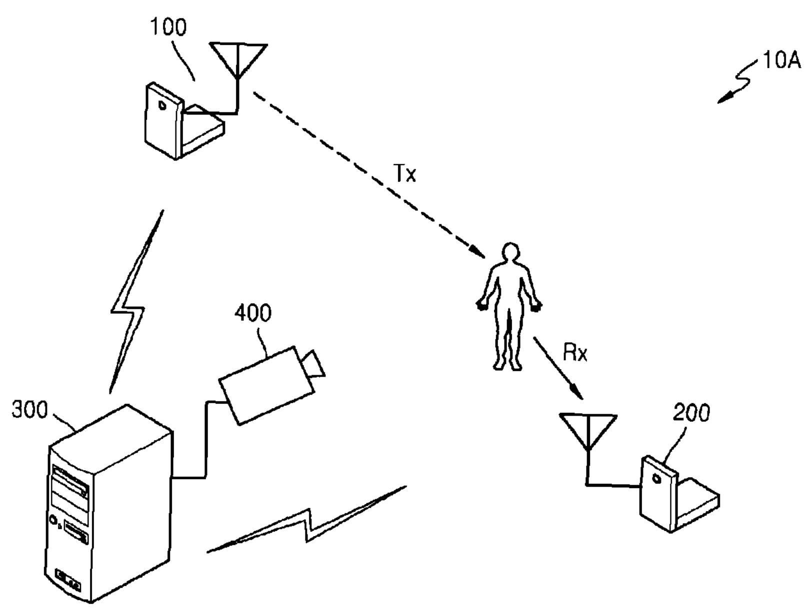


FIG. 2

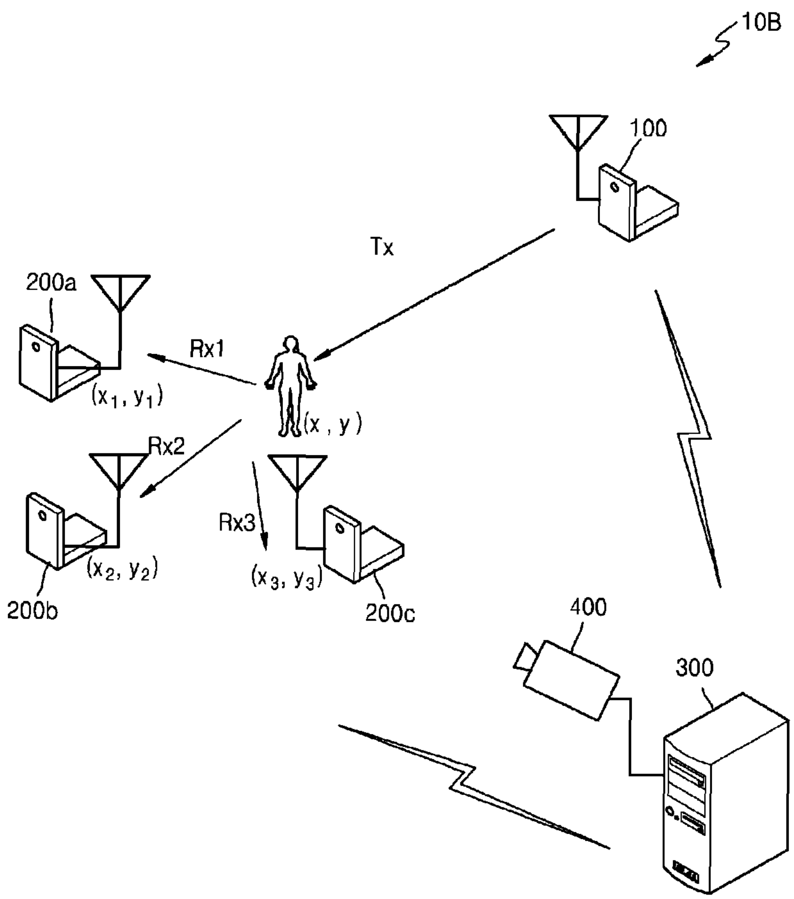


FIG. 3

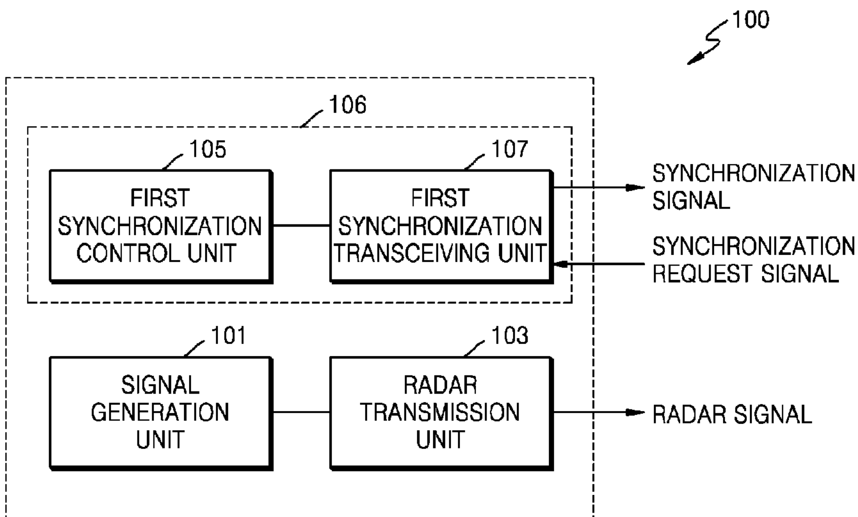

100
106
105
FIRST SYNCHRONIZATION CONTROL UNIT
107
FIRST SYNCHRONIZATION TRANSCEIVING UNIT
SYNCHRONIZATION SIGNAL
SYNCHRONIZATION REQUEST SIGNAL
101
SIGNAL GENERATION UNIT
103
RADAR TRANSMISSION UNIT
RADAR SIGNAL

FIG. 4

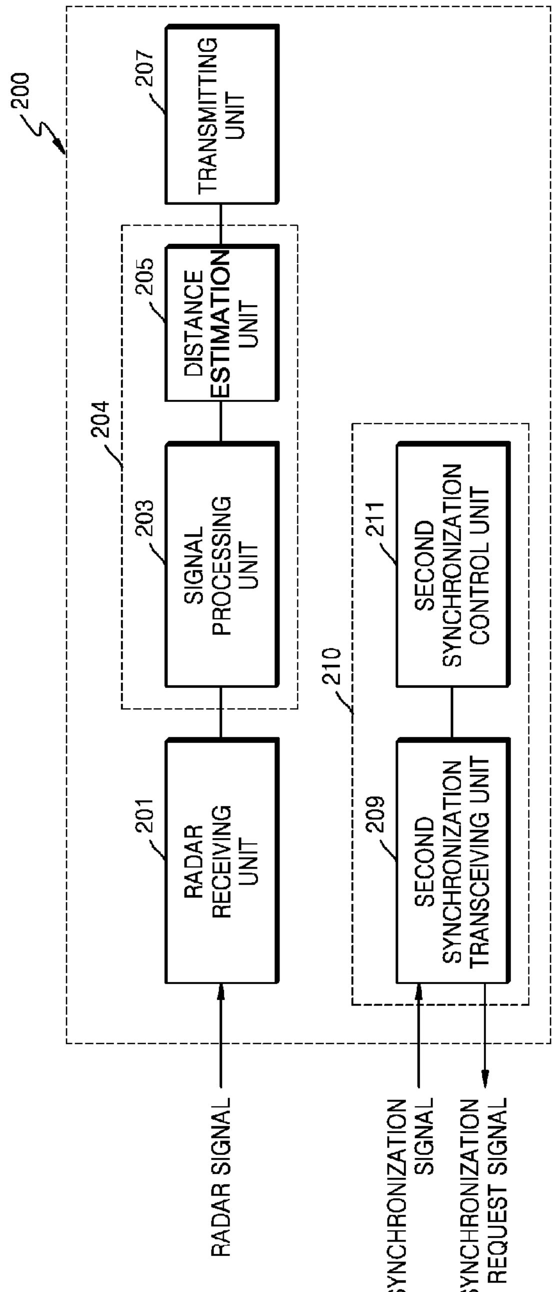
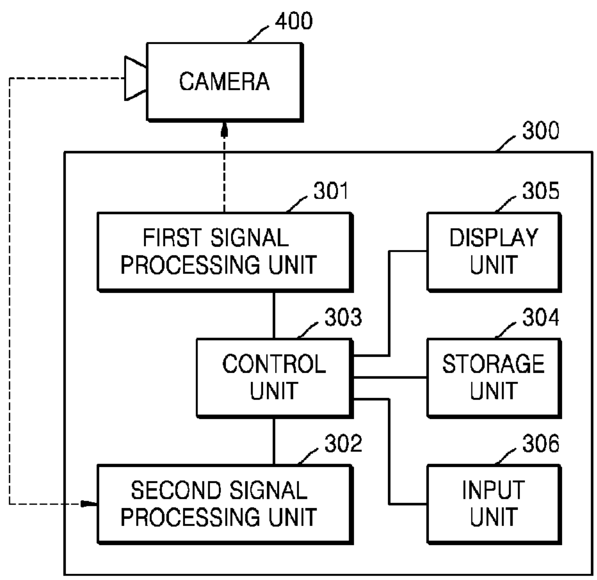
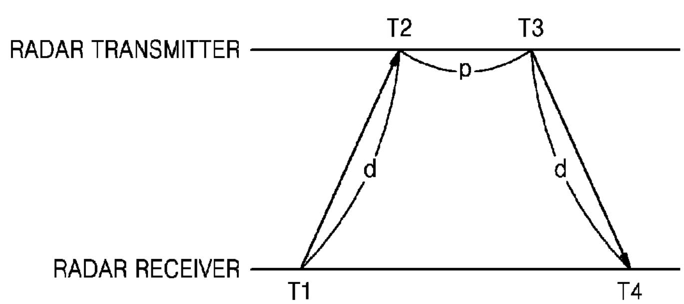

200
201
RADAR RECEIVING UNIT
203
SIGNAL PROCESSING UNIT
204
205
DISTANCE ESTIMATION UNIT
207
TRANSMITTING UNIT
209
SECOND SYNCHRONIZATION TRANSCEIVING UNIT
210
211
SECOND SYNCHRONIZATION CONTROL UNIT
RADAR SIGNAL
SYNCHRONIZATION SIGNAL
SYNCHRONIZATION REQUEST SIGNAL

FIG. 5



400
CAMERA
300
301
FIRST SIGNAL PROCESSING UNIT
305
DISPLAY UNIT
303
CONTROL UNIT
304
STORAGE UNIT
302
SECOND SIGNAL PROCESSING UNIT
306
INPUT UNIT

FIG. 6



T2
T3
RADAR TRANSMITTER
p
d
d
RADAR RECEIVER
T1
T4

FIG. 7

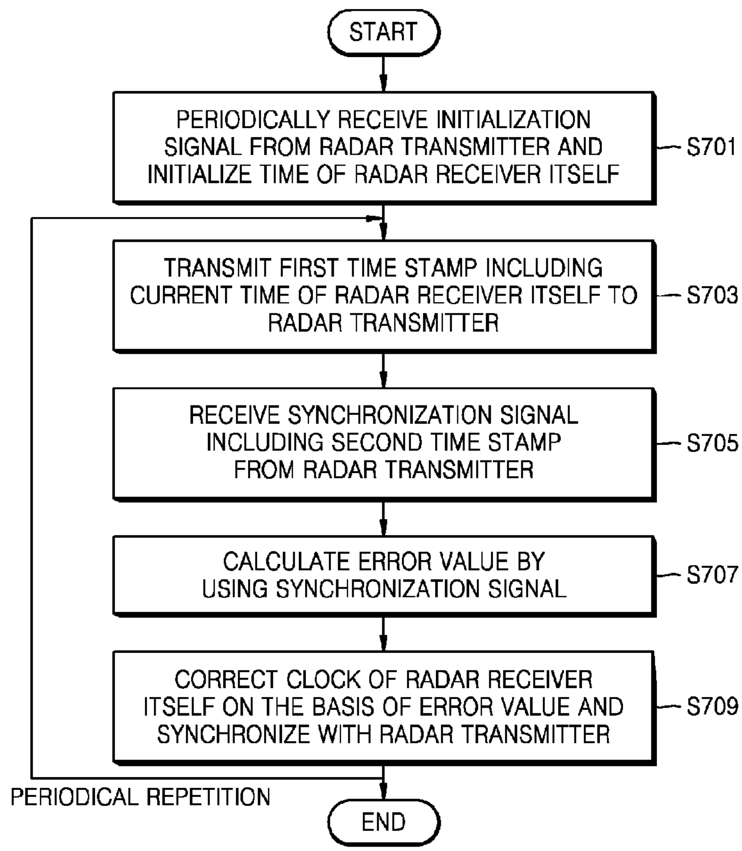

START
PERIODICALLY RECEIVE INITIALIZATION SIGNAL FROM RADAR TRANSMITTER AND INITIALIZE TIME OF RADAR RECEIVER ITSELF
S701
TRANSMIT FIRST TIME STAMP INCLUDING CURRENT TIME OF RADAR RECEIVER ITSELF TO RADAR TRANSMITTER
S703
RECEIVE SYNCHRONIZATION SIGNAL INCLUDING SECOND TIME STAMP FROM RADAR TRANSMITTER
S705
CALCULATE ERROR VALUE BY USING SYNCHRONIZATION SIGNAL
S707
CORRECT CLOCK OF RADAR RECEIVER ITSELF ON THE BASIS OF ERROR VALUE AND SYNCHRONIZE WITH RADAR TRANSMITTER
S709
PERIODICAL REPETITION
END

FIG. 8A

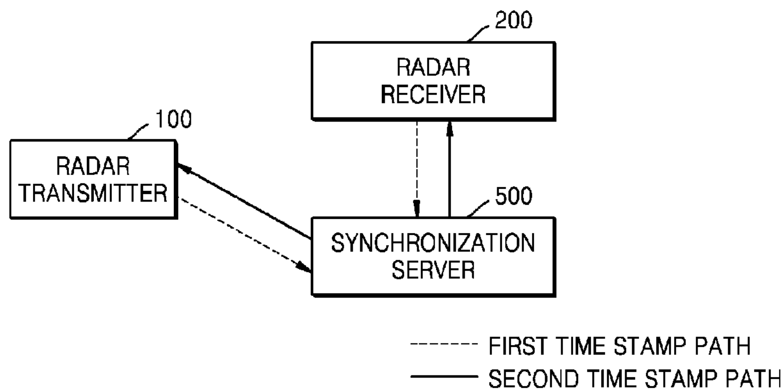

200
RADAR RECEIVER
100
RADAR TRANSMITTER
500
SYNCHRONIZATION SERVER
FIRST TIME STAMP PATH
SECOND TIME STAMP PATH

FIG. 8B

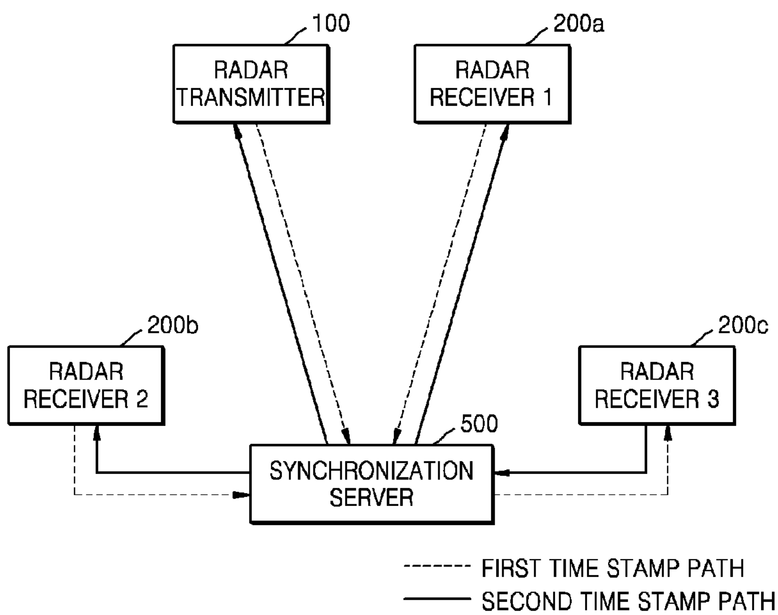

100
RADAR TRANSMITTER
200a
RADAR RECEIVER 1
200b
RADAR RECEIVER 2
200c
RADAR RECEIVER 3
500
SYNCHRONIZATION SERVER
FIRST TIME STAMP PATH
SECOND TIME STAMP PATH

FIG. 9

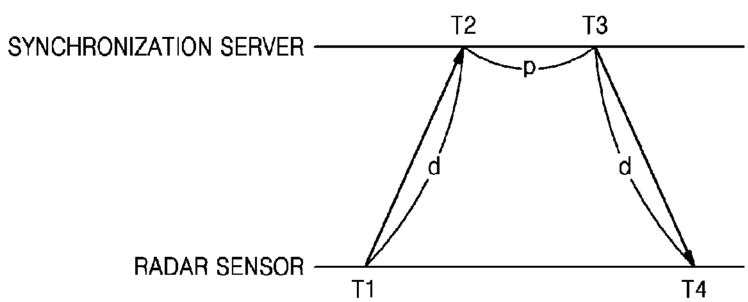


FIG. 10

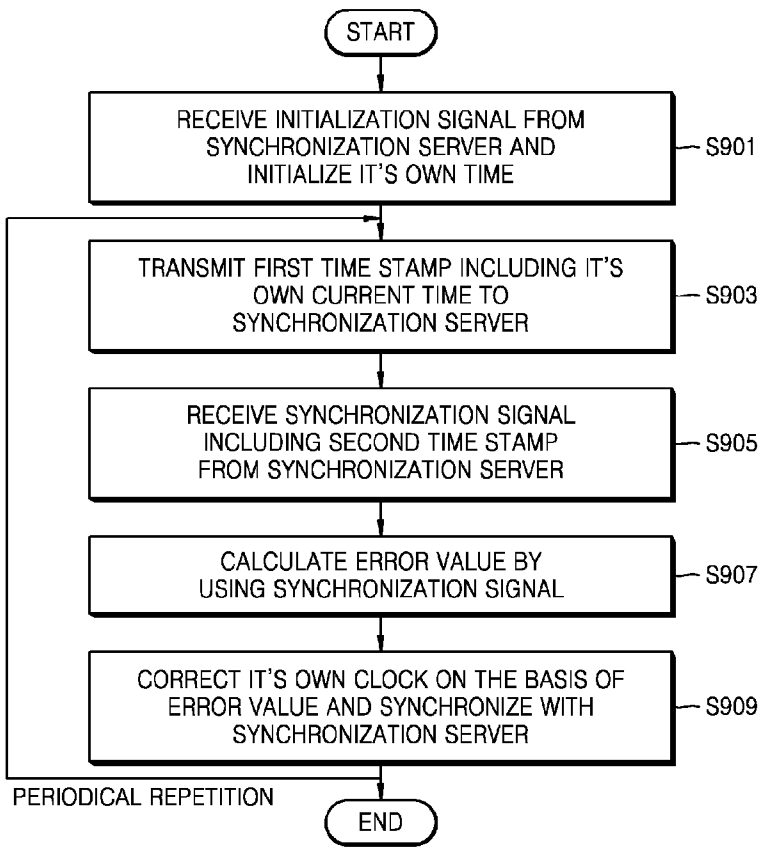
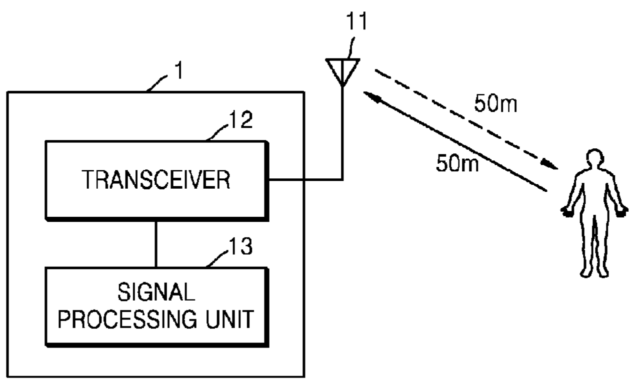

START
RECEIVE INITIALIZATION SIGNAL FROM SYNCHRONIZATION SERVER AND INITIALIZE IT'S OWN TIME
S901
TRANSMIT FIRST TIME STAMP INCLUDING IT'S OWN CURRENT TIME TO SYNCHRONIZATION SERVER
S903
RECEIVE SYNCHRONIZATION SIGNAL INCLUDING SECOND TIME STAMP FROM SYNCHRONIZATION SERVER
S905
CALCULATE ERROR VALUE BY USING SYNCHRONIZATION SIGNAL
S907
CORRECT IT'S OWN CLOCK ON THE BASIS OF ERROR VALUE AND SYNCHRONIZE WITH SYNCHRONIZATION SERVER
S909
PERIODICAL REPETITION
END

FIG. 11



SURVEILLANCE SYSTEM AND METHOD

CROSS-REFERENCE TO RELATED PATENT APPLICATION

This application claims priority from Korean Patent Application No. 10-2011-0105536, filed on Oct. 14, 2011, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein in its entirety by reference.

BACKGROUND

1. Field

Apparatuses and method consistent with exemplary embodiments relate to a surveillance system and a surveillance method that use a radar sensor.

2. Description of the Related Art

Radar sensors detect and track an object that enters a surveillance region, and ascertain information about a location of the object, by using a radio frequency (RF) signal as a radar signal.

FIG. **11** is a schematic view of a related art radar sensor **1** including a transceiver **12**. Referring to FIG. **11**, the related art radar sensor **1** includes an antenna **11**, the transceiver **12**, and a signal processing unit **13**. The transceiver **12** outputs a radar signal to an object via the antenna **11** and receives a signal reflected from an object. The radar signal transmitted to the object travels in a straight line to the object and is then reflected from the object to return to the transceiver **12**. The signal processor **13** may ascertain a distance, a direction, and an altitude of the object by measuring a period of time during which a signal is transmitted, reflected, and returns to the transceiver **12**, and may obtain information about the object via the distance, the direction, and the altitude of the object.

General civilian radar sensors restricted by local regulations have restrictions on an object detection range due to a limitation in an intensity of RF radiation power. In other words, in the related art radar sensor **1** using a transceiver, as illustrated in FIG. **11**, for example, a radar sensor having a detection range of 50 m due to a limitation in RF radiation power, a wireless radar signal moves 50 m along a transmission path and 50 m along a reception path, and thus, an overall link budget corresponds to 100 m. Therefore, for example, an application having an object detection distance of 50 m or greater needs to use other radar sensors having larger detection ranges.

SUMMARY

One or more exemplary embodiments provide a radar transmitter, a radar receiver, a surveillance system including the radar transmitter and the radar receiver, and a surveillance method that use the surveillance system capable of increasing an object detection range.

According to an aspect of an exemplary embodiment, there is provided a radar receiver including: a signal receiving unit which receives a signal reflected from an object based on a detection signal transmitted from a radar transmitter, which is separately disposed from the radar receiver and the object in a surveillance zone; and a signal processor which, based on the reflected signal, estimates a signal distance of the object which is a sum of a distance from the radar transmitter to the object and a distance from the object to the radar receiver. The signal may be a radio frequency (RF) signal.

The radar receiver may further include a synchronizer which receives a synchronization signal from at least one of the radar transmitter and a server, and may control the radar receiver to synchronize with the at least one of the radar transmitter and the server using the synchronization signal, wherein the signal processor estimates the signal distance of the object further based on the synchronization signal.

The synchronization signal may be a specific single signal or a specific sequence of signals.

The synchronizer may transmit a synchronization request signal to the at least one of the radar transmitter and the server, and receive the synchronization signal in response to the synchronization request signal.

The synchronization request signal may include a first time stamp indicating a time when the synchronizer transmits the synchronization request signal to the at least one of the radar transmitter and the server, and the synchronization signal may include a second time stamp indicating a time when the at least one of the radar transmitter and the server transmits the synchronization signal to the synchronizer of the radar receiver, and the synchronizer may calculate an error value by using the synchronization signal and control the radar receiver to synchronize with the at least one of the radar transmitter and the server.

The second time stamp may further indicate a time when the at least one of the radar transmitter and the server receives the synchronization request signal, and the synchronizer may calculate the error value by further using a time when the synchronizer receives the synchronization signal.

If the synchronization signal is received from the transmitter, the synchronization signal may include an identification code which identifies the radar transmitter from another radar transmitter and the server.

The signal receiving unit of the radar receiver may further receive the detection signal transmitted from the transmitter, and estimate the signal distance based on the reflected signal and the detection signal.

According to an aspect of another exemplary embodiment, there is provided a radar transmitter including: a signal transmitting unit which transmits a detection signal to an object which exists in a surveillance zone; and a synchronizer which performs synchronization with a radar receiver which exists in the surveillance zone separately from the radar transmitter and receives a signal reflected from the object based on the detection signal, wherein the radar receiver estimates a signal distance of the object which is a sum of a distance between the radar transmitter and the object and a distance between the object and the radar receiver based on the reflected signal.

The synchronizer of the radar transmitter may transmit a synchronization signal to the radar receiver to perform the synchronization with the radar receiver or receive a synchronization signal from a server installed outside the radar transmitter to perform the synchronization with the radar receiver.

According to an aspect of another exemplary embodiment, there is provided a surveillance system including the radar transmitter and the radar receiver described above.

The radar transmitter may include: a signal transmitting unit which transmits the detection signal to the object; and a synchronizer which transmits a synchronization signal to the radar receiver, which exists in the surveillance zone separately from the radar transmitter and receives the reflected signal, to synchronize with the radar receiver.

The synchronization signal may be a specific single signal or a specific sequence of signals.

The radar receiver may estimate the signal distance of the object further based on the detection signal and the synchronization signal.

The surveillance system may further include a video processing device which receives the signal distance from the radar receiver to detect a location of the object, and generates a control signal for controlling a camera to be directed toward the object, to control a photographing direction of the camera.

According to an aspect of an exemplary embodiment, there is provided a surveillance method including: receiving, at a radar receiver, a signal reflected from an object based on a detection signal transmitted from a transmitter, which is separately disposed from the radar receiver and the object in a surveillance zone; and estimating a signal distance of the object which is a sum of a distance from the radar transmitter to the object and a distance from the object to the radar receiver, based on the reflected signal.

The method may further include: receiving at the radar receiver a synchronization signal from at least one of the radar transmitter and a server; and controlling the radar receiver to synchronize with the at least one of the radar transmitter and the server using the synchronization signal, wherein the signal distance of the object is estimated further based on the synchronization signal.

The method may further include transmitting a synchronization request signal from the radar receiver to the at least one of the radar transmitter and the server, wherein the synchronization signal is received in response to the synchronization request signal.

The synchronization request signal may include a first time stamp indicating a time when the radar receiver transmits the synchronization request signal to the at least one of the radar transmitter and the server. The synchronization signal may include a second time stamp indicating a time when the at least one of the radar transmitter and the server transmits the synchronization signal to the radar receiver. The controlling the radar receiver to synchronize may be performed by calculating an error value by using the synchronization signal.

The second time stamp may further indicate a time when the at least one of the radar transmitter and the server receives the synchronization request signal, and the calculating the error value may be performed further using a time when the radar receiver receives the synchronization signal.

According to the exemplary embodiments, an object detection range may be increased by the surveillance system separately including the radar transmitter and the radar receiver. Moreover, the accuracy of object detection may be increased by periodical synchronization.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other aspects will become more apparent by describing in detail exemplary embodiments with reference to the attached drawings, in which:

FIG. **1** illustrates a radar-based surveillance system according to an exemplary embodiment;

FIG. **2** illustrates a radar-based surveillance system according to another exemplary embodiment;

FIG. **3** is a schematic block diagram of an internal structure of a radar transmitter according to an exemplary embodiment;

FIG. **4** is a schematic block diagram of an internal structure of a radar receiver according to an exemplary embodiment;

FIG. **5** is a schematic block diagram of an internal structure of a video processing device according to an exemplary embodiment;

FIGS. **6** and **7** are views for schematically explaining synchronization between a radar transmitter and a radar receiver, according to an exemplary embodiment;

FIGS. **8**A and **8**B are block diagrams of a network system for synchronization between a radar transmitter and a radar receiver according to exemplary embodiments;

FIGS. **9** and **10** are views for schematically explaining the synchronization between a radar transmitter and a radar receiver performed by the network system of FIGS. **8**A and **8**B, according to exemplary embodiments; and

FIG. **11** is a schematic view of a related art radar sensor including a transceiver.

DETAILED DESCRIPTION

Hereinafter, exemplary embodiments will be described more fully with reference to the accompanying drawings Like numbers refer to like elements throughout. In the description of the exemplary embodiments, if it is determined that a detailed description of commonly-used technologies or structures related to the inventive concept may unnecessarily obscure the subject matter of the exemplary embodiments, the detailed description will be omitted.

It will be understood that, although the terms 'first', 'second', 'third', etc., may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another element. For example, a first element discussed below could be termed a second element, and similarly, a second element may be termed a first element without departing from the teachings of this disclosure. Moreover, a series of processes according to the exemplary embodiments include not only sequentially performed processes but also processes performed individually or in parallel.

FIG. **1** illustrates a radar-based surveillance system **10**A according to an exemplary embodiment.

Referring to FIG. **1**, the radar-based surveillance system **10**A includes a radar sensor including a radar transmitter **100** and a radar receiver **200**, and a video processing device **300**.

The radar sensor detects and tracks an object that enters a surveillance region, and detects a location of the object, by using a radio frequency (RF) signal as a radar signal. In the radar sensor according to the present embodiment, the radar transmitter **100** and the radar receiver **200** are installed separate from each other within the surveillance region.

A related art radar sensor including a transceiver has a limitation in an object detection range because it detects an object by using a signal returning by being reflected from the object. On the other hand, a radar sensor according to the present embodiment may increase an object detection range by using a transmission path and a reception path for the radar signal independently. For example, compared to a related art transceiver-based radar sensor having a detection range of 50 m, radar sensors according to exemplary embodiments may include a radar transmitter and a radar receiver spaced by a distance of 100 m and may detect an object existing in the distance of 100 m therebetween to estimate a distance of an object. Accordingly, the object detection range may be increased to 100 m.

The radar transmitter **100** periodically outputs a radar signal.

The radar receiver **200** receives an output radar signal Tx of the radar transmitter **100** and a reflected radar signal Rx obtained by reflection of the output radar signal Tx from the object. The radar receiver **200** may analyze the output radar signal Tx and the reflected radar signal Rx to detect a length of an entire path along which the radar signal is transmitted by the radar transmitter **100**, reflected by the object, and received by the radar receiver **200** (hereinafter, referred to as a signal distance of an object).

At this time, the radar transmitter **100** and the radar receiver **200** may be synchronized with each other by a synchronization signal.

The radar receiver **200** transmits the signal distance of the object to the video processing device **300**.

The video processing device **300** is connected to a camera **400** in a wired/wireless manner, receives the signal distance of the object from the radar receiver **200**, and calculates the location of the detected object in cooperation with the radar receiver **200**.

The video processing device **300** estimates the location of the object based on the signal distance of the object and directs the camera **400** toward the object to monitor the object.

FIG. **2** illustrates a radar-based surveillance system **10**B according to another exemplary embodiment.

Referring to FIG. **2**, the radar-based surveillance system **10**B includes a radar sensor including the radar transmitter **100** and a plurality of radar receivers **200***a*, **200***b*, and **200***c*, and the video processing device **300**. The embodiment of FIG. **2** is the same as that of FIG. **1** except for the radar receivers **200***a*, **200***b*, and **200***c*.

The video processing device **300** may detect information about a location of an object based on at least three signal distances of an object and estimate the location of the object. Accordingly, the three radar receivers **200***a*, **200***b*, and **200***c* are illustrated in the present embodiment.

As in the radar sensor of FIG. **1**, in the radar sensor according to the present embodiment, the radar transmitter **100** and the radar receivers **200***a*, **200***b*, and **200***c* are installed separate from each other within a surveillance region. Accordingly, like the radar sensor of FIG. **1**, the radar sensor of FIG. **2** may also increase an object detection range, compared to related art radar sensors including a transceiver.

The radar transmitter **100** periodically outputs a radar signal.

The radar receivers **200***a*, **200***b*, and **200***c* receive an output radar signal Tx of the radar transmitter **100** and reflected radar signals Rx**1**, Rx**2**, and Rx**3** obtained by reflection of the output radar signal Tx from the object, respectively.

The radar receivers **200***a*, **200***b*, and **200***c* are spaced apart from one another. The radar receivers **200***a*, **200***b*, and **200***c* may analyze the output radar signal Tx and the reflected radar signals Rx**1**, Rx**2**, and Rx**3**, respectively, to detect the signal distance of the object, namely, a length of an entire path along which a radar signal is transmitted by the radar transmitter **100**, reflected by the object, and received at respective locations (x1,y1), (x2,y2), and (x3,y3) of the radar receivers **200***a*, **200***b*, and **200***c*.

At this time, the radar transmitter **100** and the radar receivers **200***a*, **200***b*, and **200***c* may be synchronized with one another by a synchronization signal.

The radar receivers **200***a*, **200***b*, and **200***c* transmit three signal distances of the object to the video processing device **300**.

Although a single radar transmitter **100** and three radar receivers **200***a*, **200***b*, and **200***c* are illustrated in FIG. **2**, a number of the radar sensors is not limited thereto, and it may include at least one radar transmitter and at least one radar receiver arranged within a surveillance region.

The video processing device **300** is connected to the camera **400** in a wired/wireless manner, receives the signal distances of the object from the radar receivers **200***a*, **200***b*, and **200***c*, and monitors the detected object in cooperation with the radar receivers **200***a*, **200***b*, and **200***c*.

The video processing device **300** estimates the location of the object based on the signal distances of the object and directs the camera **400** toward the object to monitor the object.

FIG. **3** is a schematic block diagram of an internal structure of the radar transmitter **100**, according to an exemplary embodiment.

Referring to FIG. **3**, the radar transmitter **100** may include a signal generation unit **101**, a radar transmission unit **103**, a first synchronization control unit **105**, and a first synchronization transceiving unit **107**. The first synchronization control unit **105** and the first synchronization transceiving unit **107** may be collectively constituted as a synchronizer **106**.

The signal generation unit **101** generates a radar signal to be transmitted. The radar signal is an RF signal which may have a predetermined frequency, and may be converted into a pulse-type radar signal.

The radar transmission unit **103** may output the pulse-type radar signal to a surveillance region via an antenna. The radar transmission unit **105** may periodically output the radar signal to the surveillance region while the radar transmitter **100** is fixed or rotates within a predetermined range.

The first synchronization control unit **105** synchronizes with the radar receiver **200** shown in FIG. **1** or the three radar receivers **200***a*, **200***b*, and **200***c* shown in FIG. **2**, which are arranged apart from the radar transmitter **100**. The first synchronization control unit **105** may be synchronized with the radar receiver **200** or the three radar receivers **200***a*, **200***b*, and **200***c* directly or via a server.

When receiving a synchronization request signal from the radar receiver **200** or the three radar receivers **200***a*, **200***b*, and **200***c* via the first synchronization transceiving unit **107**, the first synchronization control unit **105** may generate a synchronization signal and transmit the same to the radar receiver **200** or the three radar receivers **200***a*, **200***b*, and **200***c* via the first synchronization transceiving unit **107**. Alternatively, the first synchronization control unit **105** may transmit a synchronization request signal to a server via the first synchronization transceiving unit **107** and receive a synchronization signal from the server so as to be synchronized with the server, thereby synchronizing with the radar receiver **200** or the three radar receivers **200***a*, **200***b*, and **200***c*. The synchronization request signal and the synchronization signal may be transmitted and received along a wired/wireless network path different from transmission and reception paths for the radar signal.

The first synchronization transceiving unit **107** may include an identification code of the radar transmitter **100** in the synchronization signal.

The synchronization signal is a signal pre-arranged between the radar transmitter **100** and either the radar receiver **200** or the three radar receivers **200***a*, **200***b*, and **200***c*, and may be defined as a specific single signal or a specific sequence of signals. The synchronization signal may be generated periodically or non-periodically. The synchronization request signal and the synchronization signal include time information.

In addition, the first synchronization control unit **105** may periodically generate an initialization signal including an absolute time of the radar transmitter **100** itself, and the first synchronization transceiving unit **107** may transmit the initialization signal to the radar receiver **200** or the three radar receivers **200***a*, **200***b*, and **200***c*. Alternatively, the first synchronization control unit **105** may periodically receive an initialization signal including an absolute time of a server from the server via the first synchronization transceiving unit **107** and may perform time initialization.

FIG. **4** is a schematic block diagram of an internal structure of a radar receiver **200** according to an exemplary embodiment. The radar receiver **200** of FIG. **4** may be each of the radar receivers **200**, **200***a*, **200***b*, and **200***c*, and the radar receiver **200** of FIG. **1** will now be described as an example.

Referring to FIG. **4**, the radar receiver **200** may include a radar receiving unit **201**, a signal processing unit **203**, a distance estimation unit **205**, a transmitting unit **207**, a second synchronization transceiving unit **209**, and a second synchronization control unit **211**. The signal processing unit **203** and the distance estimating unit **205** may be collectively constituted as a signal processor **204**. The second synchronization transceiving unit **209** and the second synchronization control unit **211** may be collectively constituted as a synchronizer **210**.

The radar receiving unit **201** receives a radar signal from the radar transmitter **100** via an antenna and receives a radar signal reflected from the object.

The signal processing unit **203** removes clutter and noise from the received radar signal. For example, the signal processing unit **203** may remove clutter and noise by using a loop-filter algorithm, a singular value decomposition (SVD) algorithm, or the like. However, various other methods may be used to remove clutter and noise.

The distance estimation unit **205** may estimate a signal distance of the object based on the radar signal output by the radar transmitter **100** and the radar signal reflected by the object. The distance estimation unit **205** may measure a time difference between the radar signal output by the radar transmitter **100** and the radar signal reflected by the object by using a cross correlation function, and may estimate the distance of the object based on the time difference.

The transmitting unit **207** may transmit information about the estimated distance of the object to the video processing device **300** in a wired/wireless manner.

The second synchronization control unit **211** may generate a synchronization request signal to synchronize with the radar transmitter **100**, and transmit the same to the radar transmitter **100** via the second synchronization transceiving unit **209**. The second synchronization control unit **211** may receive a synchronization signal from the radar transmitter **100** via the second synchronization transceiving unit **209**, and may synchronize with the radar transmitter **100** and other neighboring radar receivers according to the synchronization signal. Alternatively, the second synchronization control unit **211** may transmit a synchronization request signal to a server via the second synchronization transceiving unit **209** and receive a synchronization signal from the server so as to be synchronized with the server, thereby synchronizing with the radar transmitter **100** and other neighboring radar receivers. The synchronization request signal and the synchronization signal may be transmitted and received via a wired/wireless network path different from transmission and reception paths for the radar signal. The synchronization request signal and the synchronization signal include time information.

The second synchronization control unit **211** may extract an identification code from the synchronization signal, and may ascertain which one of a plurality of radar transmitters **100** has transmitted the synchronization signal, based on the identification code.

The second synchronization transceiving unit **209** may periodically receive an initialization signal including an absolute time of the radar transmitter **100** or an absolute time of the server from the radar transmitter **100** or the server, respectively, and the second synchronization control unit **211** may periodically initialize its own time.

FIG. **5** is a schematic block diagram of an internal structure of the video processing device **300**, according to an exemplary embodiment.

Referring to FIG. **5**, the video processing device **300** is connected to any of various types of cameras, such as a pan-tilt-zoom (PTZ) camera **400**, by wires or wirelessly. Examples of the video processing device **300** may include a digital video recorder (DVR) and/or a network video recorder (NVR), which are widely used as a closed-circuit TV (CCTV) system, and also a personal computer (PC) or a server for storing data under a cloud computing environment and a mobile device.

The video processing device **300** may include a first signal processing unit **301**, a second signal processing unit **302**, a control unit **303**, a storage unit **304**, a display unit **305**, and an input unit **306**.

The first signal processing unit **301** receives information about a signal distance of an object from a radar sensor **100**. The first signal processing unit **301** may receive signal distances of the object from a plurality of radar receivers **200**. For example, referring to FIGS. **2** and **5**, the first signal processing unit **301** may detect information about a location of the object based on respective signal distances of the object received from at least three radar receivers, namely, the radar receives **200***a*, **200***b*, and **200***c*, and estimate the location of the object. The information about the location of the object includes a distance, a direction, and an altitude of the object.

At this time, the radar transmitter **100** and the radar receivers **200***a*, **200***b*, and **200***c* may be synchronized with one another by a synchronization signal. Accordingly, the first signal processing unit **301** may accurately detect the location of the object by using respective signal distances of the object that the radar receivers **200***a*, **200***b*, and **200** have estimated based on the reflected radar signal Rx obtained by the object reflecting the output radar signal Tx.

The first signal processing unit **301** may generate a camera control signal that controls the camera **400** to be directed toward the detected object, based on the information about the location of the object, and may output the camera control signal to the camera **400**. The camera control signal includes a panning value and a tilting value used to rotate the camera **400** in horizontal and vertical directions, respectively, and a zooming value representing an image magnification rate, and thus, may set a photographing direction of the camera **400** and the focus thereof.

Although the first signal processing unit **301** generates and provides the camera control signal to the camera **400** in the present embodiment, the first signal processing unit **301** may provide the information about the location of the object to the camera **400** so that the camera **400** generates a camera control signal based on the information about the location of the object and sets a photographing direction of the camera **400** and the focus thereof.

The second signal processing unit **302** receives an image captured by the camera **400** directed toward the detected object, and processes the image according to a pre-set algorithm.

The control unit **303** controls each component of the video processing device **300**. When the first signal processing unit **302** receives the signal distance of the object from the radar sensor **100**, the control unit **303** may control the video processing device **300** to be activated in a standby mode and to be converted from the standby mode to a surveillance mode.

The storage unit **304** stores an image output by the second signal processing unit **302**. The control unit **303** may set a field for storing time information and a field for storing the information about the location of the object, in the storage unit **304**. Accordingly, the storage unit **304** may store the time information and the information about the location of the object, together with the image. The storage unit **304** may be a magnetic disk, a memory card, an optical disk, or the like that may be built or installed in the video processing device **300**.

The display unit **305** displays the image output by the second signal processing unit **302** or menu items or the like produced according to a control signal received via the input unit **306**. When a user requests an image search via the input unit **305**, the display unit **305** may display menu items or the like that allows the user to directly or indirectly select a type and location of an object, a specific time, and the like. The display unit **305** may provide visual information and/or auditory information to the user, and the display unit **305** may be a liquid crystal display (LCD) panel, an organic light-emitting display panel (OLED), an electrophoretic display (EPD), or the like. The display unit **205** may take a form of a touch screen to receive user input via touching, and may operate as a user interface.

The input unit **306** may be implemented by using hardware or software. When the input unit **306** is implemented by using hardware, it may receive a signal via a wired/wireless remote controller or via a menu button integrated into the display unit **305**. When the input unit **306** is implemented by using software, it may be displayed on the screen of the display unit **305** and may receive signals via a pointing device, such as a mouse, a keyboard, or a track ball, or via touch screen sensitivity, such as a finger, a pen, or a stylus system.

FIGS. **6** and **7** are views for schematically explaining synchronization between a radar transmitter and a radar receiver, according to an exemplary embodiment.

Referring to FIGS. **6** and **7**, first, the radar receiver periodically receives an initialization signal from the radar transmitter and initializes a time of the radar receiver itself, in operation S**701**. The radar transmitter, periodically, for example, once a day, transmits an initialization signal including an absolute time of the radar transmitter to the radar receiver.

In operation S**703**, the time-initialized radar receiver transmits a first time stamp as a synchronization request signal to the radar transmitter. The first time stamp is a current time of the radar receiver, and includes a first time T**1** when the radar receiver transmits the first time stamp to the radar transmitter.

In operation S**705**, the radar receiver receives a synchronization signal including a second time stamp, from the radar transmitter. The radar transmitter generates the second time stamp based on the first time stamp, and transmits the second time stamp to the radar receiver. The second time stamp includes the first time T**1**, a second time T**2** when the radar transmitter receives the first time stamp from the radar receiver, and a third time T**3** when the radar transmitter transmits the second time stamp to the radar receiver.

In operation S**707**, the radar receiver calculates an error value Δ by using the synchronization signal. The radar receiver may calculate the error value Δ by using a round trip time (RTT) from the first time T**1** when the radar receiver transmits the first time stamp to the radar transmitter to a fourth time T**4** when the radar receiver receives the synchronization signal including the second time stamp from the radar transmitter. The error value Δ is a clock difference between a radar transmitter RTx and a radar receiver RRx. The error value Δ may be calculated using Equations (1) through (5):

$$T_1^{RRx} + \Delta + d = T_2^{RTx} \tag{1}$$

$$p + 2d = T_4^{RRx} - T_1^{RRx} \tag{2}$$

$$p = T_3^{RTx} - T_2^{RTx} \tag{3}$$

$$d = \frac{T_4^{RRx} - T_1^{RRx} - (T_3^{RTx} - T_2^{RTx})}{2} \tag{4}$$

-continued

$$\Delta = T_2^{RTx} - T_1^{RRx} - \frac{T_4^{RRx} - T_1^{RRx} - (T_3^{RTx} - T_2^{RTx})}{2} \tag{5}$$

where d denotes a time period required for the radar receiver to transmit the first time stamp to the radar transmitter and a time period required for the radar transmitter to transmit the second time stamp to the radar receiver, and p denotes a time period required for the radar transmitter to receive the first time stamp and transmit the second time stamp.

In other words, the error value Δ may be calculated by using the first time T**1** when the radar receiver transmits the first time stamp to the radar transmitter, the second time T**2** when the radar transmitter receives the first time stamp from the radar receiver, the third time T**3** when the radar transmitter transmits the second time stamp to the radar receiver, and the fourth time T**4** when the radar receiver receives the second time stamp from the radar transmitter.

In operation S**709**, the radar receiver corrects its own clock based on the error value Δ and synchronizes with the radar transmitter.

The radar receiver may repeat operations S**703** through S**709** periodically, for example, every hour, to be synchronized with the radar transmitter.

FIGS. **8**A and **8**B are block diagrams of a network system for synchronization between a radar transmitter and a radar receiver according to another exemplary embodiment. FIGS. **9** and **10** are views for schematically explaining the synchronization between the radar transmitter and the radar receiver performed by the network system of FIGS. **8**A and **8**B.

In the network system of FIGS. **8**A and **8**B, synchronization between the radar transmitter **100** and either the single radar receiver **200** or a plurality of radar receivers, namely, the radar receivers **200***a*, **200***b*, and **200***c*, is performed via a synchronization server **500**. The synchronization server **500** may include a management module for managing the radar transmitter **100** and either the radar receiver **200** or the radar receivers **200***a*, **200***b*, and **200***c*, and a synchronization module for synchronization.

Referring to FIGS. **9** and **10**, first, the radar transmitter **100** and either the radar receiver **200** or the radar receivers **200***a*, **200***b*, and **200***c* periodically receive an initialization signal from the synchronization server **500** and initialize their own time, in operation S**901**. The synchronization server **500** periodically, for example, once a day, transmits an initialization signal including its own absolute time to the radar transmitter **100** and either the radar receiver **200** or the radar receivers **200***a*, **200***b*, and **200***c*. A radar sensor of FIGS. **8**A and **8**B may be the radar transmitter **100** or each of the radar receivers **200**, **200***a*, **200***b*, and **200***c*. The radar transmitter **100** or each of the radar receivers **200**, **200***a*, **200***b*, and **200***c* will now be referred to as a radar sensor.

In operation S**903**, a time-initialized radar sensor transmits a first time stamp as a synchronization request signal to the synchronization server **500**. The first time stamp is a current time of the radar sensor, and includes a first time T**1** when the radar sensor transmits the first time stamp to the synchronization server **500**.

In operation S**905**, the radar sensor receives a synchronization signal, including a second time stamp, from the synchronization server **500**. The synchronization server **500** generates the second time stamp based on the first time stamp, and transmits the second time stamp to the radar sensor. The second time stamp includes the first time T**1**, a second time T**2** when the synchronization server **500** receives the first time stamp from the radar sensor, and a third time T**3** when the synchronization server **500** transmits the second time stamp to the radar sensor.

In operation S**907**, the radar sensor calculates an error value Δ by using the synchronization signal. The radar sensor may calculate the error value Δ by using an RTT from the first time T**1** when the radar sensor transmits the first time stamp to the synchronization server **500** to a fourth time T**4** when the radar sensor receives the synchronization signal, including the second time stamp, from the synchronization server **500**. The error value Δ is a clock difference between the synchronization server **500** (i.e., Sv) and the radar sensor (i.e., Rs). The error value Δ may be calculated using Equations (6) through (10):

$$T_1^{Rs} + \Delta + d = T_2^{Sv} \tag{6}$$

$$p + 2d = T_4^{Rs} - T_1^{Rs} \tag{7}$$

$$p = T_3^{Sv} - T_2^{Sv} \tag{8}$$

$$d = \frac{T_4^{Rs} - T_1^{Rs} - (T_3^{Sv} - T_2^{Sv})}{2} \tag{9}$$

$$\Delta = T_2^{Sv} - T_1^{Rs} - \frac{T_4^{Rs} - T_1^{Rs} - (T_3^{Sv} - T_2^{Sv})}{2} \tag{10}$$

where d denotes a time period required for the radar sensor to transmit the first time stamp to the synchronization server **500** and a time period required for the synchronization server **500** to transmit the second time stamp to the radar sensor, and p denotes a time period required for the synchronization server **500** to receive the first time stamp and transmit the second time stamp.

In other words, the error value Δ may be calculated by using the first time T**1** when the radar sensor transmits the first time stamp to the synchronization server **500**, the second time T**2** when the synchronization server **500** receives the first time stamp from the radar sensor, the third time T**3** when the synchronization server **500** transmits the second time stamp to the radar sensor, and the fourth time T**4** when the radar sensor receives the second time stamp from the synchronization server **500**.

In operation S**909**, the radar sensor corrects its own clock based on the error value Δ and synchronizes with the synchronization server **500**.

The radar sensor may repeat operations S**903** through S**909** periodically, for example, every hour, to be synchronized with the synchronization server **500**.

Although the synchronization server **500** is independently included in the present exemplary embodiment, the network system of FIGS. **8**A and **8**B is not limited thereto. The synchronization server **500** may be integrated into the video processing device **300** of FIG. **1** or the radar transmitter **100**.

According to the exemplary embodiments, separate installation of a radar transmitter and a radar receiver may increase a recognition distance of an object to be detected. In addition, an installation of a single radar transmitter and a plurality of radar receivers may lead to accurate detection of a location of an object within an increased distance. According to the exemplary embodiments, a radar transmitter and a radar receiver synchronize with each other by transmitting and receiving a pre-defined signal therebetween, thereby removing a drift of a clock. According to the exemplary embodiments, a radar sensor includes a radar transmitter and a radar receiver independently, thus reducing an overall system cost compared to radar sensors including an integrated transceiver. In the meantime, the inventive concept is not limited to the exemplary embodiments as described above employing radar signals, a radar transmitter and a radar receiver. That is, the inventive concept may apply to different types of a signal and corresponding transmitter and receivers.

While the inventive concept has been particularly shown and described with reference to exemplary embodiments thereof, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope of the inventive concept as defined by the following claims.

What is claimed is:

1. A radar receiving apparatus comprising:

a signal receiving unit configured to receive an output radar signal transmitted from a radar transmitter and a signal reflected from an object, the reflected signal obtained by reflection of the output radar signal transmitted from the radar transmitter, which is separately disposed from the radar receiving apparatus and the object in a surveillance zone;

a signal processor configured to estimate, based on the reflected signal and the output radar signal, a signal distance of the object which is a sum of a distance from the radar transmitter to the object and a distance from the object to the radar receiving apparatus; and

a synchronizer which transmits a synchronization request signal to at least one of the radar transmitter and a server and receives a synchronization signal from the at least one of the radar transmitter and the server in response to the synchronization request signal, and controls the radar receiving apparatus to synchronize with the at least one of the radar transmitter and the server using the synchronization signal,

wherein the synchronization request signal comprises a first time stamp indicating a time when the synchronizer transmits the synchronization request signal to the at least one of the radar transmitter and the server,

wherein the synchronization signal comprises a second time stamp indicating a time when the at least one of the radar transmitter and the server transmits the synchronization signal to the synchronizer of the radar receiving apparatus, and

wherein the synchronizer calculates an error value by using the synchronization signal and controls the radar receiving apparatus to synchronize with the at least one of the radar transmitter and the server.

2. The radar receiving apparatus of claim **1**, wherein the second time stamp further indicates a time when the at least one of the radar transmitter and the server receives the synchronization request signal, and

wherein the synchronizer calculates the error value by further using a time when the synchronizer receives the synchronization signal.

3. The radar receiving apparatus of claim **1**, wherein if the synchronization signal is received from the radar transmitter, the synchronization signal comprises an identification code which identifies the radar transmitter from another radar transmitter and the server.

4. The radar receiving apparatus of claim **1**,

wherein the signal processor estimates the signal distance of the object further based on the synchronization signal.

5. A radar transmitting apparatus comprising:

a signal transmitting unit configured to transmit an output radar signal to an object which exists in a surveillance zone; and a synchronizer configured to perform synchronization with a radar receiver which exists in the surveillance zone separately from the radar transmitting apparatus,

wherein the radar receiver estimates a signal distance of the object which is a sum of a distance between the radar transmitting apparatus and the object and a distance between the object and the radar receiver based on the output radar signal and a signal reflected from the object, the reflected signal obtained by reflection of the output radar signal,

wherein the synchronizer of the radar transmitting apparatus is configured to transmit a synchronization signal to the radar receiver to perform the synchronization with the radar receiver or is configured to receive a synchronization signal from a server installed outside the radar transmitting apparatus to perform the synchronization with the radar receiver.

6. The radar transmitting apparatus of claim **5**, wherein the radar receiver estimates the signal distance further based on the synchronization signal.

7. The radar transmitting apparatus of claim **5**, wherein the synchronization signal comprises an identification code which identifies the radar transmitter from another radar transmitter and the server.

8. The radar transmitting apparatus of claim **5**, wherein the synchronizer which transmits a synchronization request signal to the server and receives a synchronization signal from the server in response to the synchronization request signal, and controls the radar transmitting apparatus to synchronize with the radar receiver using the synchronization signal,

wherein the synchronization request signal comprises a first time stamp indicating a time when the synchronizer transmits the synchronization request signal to the server, and

wherein the synchronization signal comprises a second time stamp indicating a time when the server transmits the synchronization signal to the synchronizer of the radar transmitting apparatus, and

wherein the synchronizer calculates an error value by using the synchronization signal and controls the radar transmitting apparatus to synchronize with the radar receiver.

9. A surveillance system comprising:

a radar transmitting apparatus;

a radar receiving apparatus comprising:

a signal receiving unit configured to receive a signal reflected from an object, the reflected signal obtained by reflection of an output radar signal transmitted from the radar transmitting apparatus, which is separately disposed from the radar receiving apparatus and the object in a surveillance zone; and

a signal processor configured to estimate, based on the output radar signal and the reflected signal, a signal distance of the object which is a sum of a distance from the radar transmitting apparatus to the object and a distance from the object to the radar receiving apparatus; and

a video processing device configured to receive the signal distance from the radar receiving apparatus to detect a location of the object, and generate a control signal for controlling a camera to be directed toward the object, to control a photographing direction of the camera.

10. The surveillance system of claim **9**, wherein the radar transmitting apparatus comprises:

a signal transmitting unit configured to transmit the output radar signal to the object; and

a synchronizer configured to transmit a synchronization signal to the radar receiving apparatus, which exists in the surveillance zone separately from the radar transmitting apparatus and receives the reflected signal, to synchronize with the radar receiving apparatus.

11. The surveillance system of claim **10**, wherein the radar receiving apparatus is configured to estimate the signal distance of the object further based on the synchronization signal.

12. A surveillance method comprising:

receiving, at a radar receiver, an output radar signal transmitted from a radar transmitter and a signal reflected from the object, the reflected signal obtained by reflection of an output radar signal transmitted from the radar transmitter, which is separately disposed from the radar receiver and the object in a surveillance zone;

estimating a signal distance of the object which is a sum of a distance from the radar transmitter to the object and a distance from the object to the radar receiver, based on the reflected signal and the output radar signal;

transmitting a synchronization request signal from the radar receiver to at least one of the radar transmitter and a server;

receiving, at the radar receiver, a synchronization signal from the at least one of the radar transmitter and a server in response to the synchronization request signal; and

synchronizing, at the radar receiver, with the at least one of the radar transmitter and the server using the synchronization signal,

wherein the synchronization request signal comprises a first time stamp indicating a time when the radar receiver transmits the synchronization request signal to the at least one of the radar transmitter and the server,

wherein the synchronization signal comprises a second time stamp indicating a time when the at least one of the radar transmitter and the server transmits the synchronization signal to the radar receiver, and

wherein the synchronizing at the radar receiver is performed by calculating an error value by using the synchronization signal.

13. The method of claim **12**,

wherein the signal distance of the object is estimated further based on the synchronization signal.

14. The method of claim **12**, wherein the second time stamp further indicates a time when the at least one of the radar transmitter and the server receives the synchronization request signal, and

wherein the calculating the error value is performed further using a time when the radar receiver receives the synchronization signal.

15. The method of claim **12**, further comprising

transmitting a synchronization request signal from the radar transmitter to the server,

receiving, at the radar transmitter, the synchronization signal from the server in response to the synchronization request signal, and

synchronizing, at the radar transmitter, with the radar receiver using the synchronization signal,

wherein the synchronizing at the radar transmitter is performed by calculating an error value by using the synchronization signal.

16. The method of claim **12**, further comprising

receiving, at a video processing device, the signal distance from the radar receiver to detect a location of the object, and

generating a control signal for controlling a camera to be directed toward the object, to control a photographing direction of the camera.

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